Optimization of Logistics Processes During the Production of Wood Chips

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Abstract **– Biomass is one of the sustainable sources for the production of heat and electricity. This paper is devoted to the processing of wood waste. It is an analysis of wood chips processing from the process of balancing the brushwood after toll harvesting, including the transport of processed wood mass to the heating company. MS Project software was used to optimize this production process.**

Keywords **– Logistics, wood chip, chipper, biomass, network analysis, CPM method, MS Project, optimization, investment.**

1. Introduction

Logistics processes have to adapt to the requirements of various fields, and also energetic field. Their main task is to ensure the proper functioning of processes, to support the production of products and the provision of services [1]. The aim is to achieve the greatest possible efficiency [2]. To achieve this goal, various methods are used, among which computer sawmills, and wood processing plants in the form of sawdust, chunks, bark and cuttings.

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This waste needs simulation, which is currently beginning to dominate [3]. At present, logistics have to adapt to the requirements of energy and sustainable development [4].

The increasing demand for renewable energy sources has resulted in an increase in the use of biomass for energy purposes [5]. Biomass is used to generate heat and electrical energy [6]. Wood mass (biomass) is generated from activities such as forest logging and the maintenance of parks, orchards and alleys in the form of trunks, branches and the crowns of trees, but also as by-products and waste that is to be processed further in order to make it fit for purpose.

Biomass needs to be transported for processing, which can sometimes be a logistically demanding process [7]. Various transport technologies are used for this, in connection with which it is necessary to solve various problem areas, such as operating costs [8]. Special uses include belt conveyors [9]. Belt conveyors offer several advantages, among which we can mention, for example, their variability and versatility [10]. Thanks to the versatility of continuous transport systems, they can be used in various forms for wood biomass processing.

One of the options for processing wood mass is chipping, whereby the input material is chipped by sharp blades into homogeneous wooden chips. The second option is crushing, whereby the input material is crushed by hammers located on a rotor. Crushers are generally used when extraneous substances are present in the wood mass [11]. Wood chips can also be used for gardening purposes (composting, mulching). For energy use, the most important parameter is moisture [12]. Technologies exist for the processing of both dry and wet wood chips [13].

2. Research and Methodology

This paper focuses on the optimization of logistics processes during the production of wood chips. The company at the heart of the study originally only supplied biomass for heating purposes to power plants in South Bohemia. Over the course of time, the volumes of tradeable material rose and the company's activities expanded. At present, the company carries out the following business activities: purchase of biomass, disposal of wood waste, extraction and disposal of brushwood, chipping and crushing, transport and storage, sale of timber [14]. At the request of the timber company, this paper focuses on the optimization of their business activities on the basis of the CPM method and with the use of MS Project [16], [17].

3. Wood Chipping Process

The processing of wood chips can be divided into several stages [18], [19]:

1) Terrain survey – Czech legislation states that the forest fund has to be protected and systematically cared for. The land should not be removed from the forest fund without due purpose. If removal is required, it is then necessary to limit this to the smallest possible area and to locate any structure on it in compliance with the interests of the forest economy and, after completion of the construction works, to implement such adjustments that the land disturbed by the construction works is eligible for the forest economy again. Based on current forest divisions, it is clear that timber intended for logging predominantly originates from forest plantations. It is therefore necessary to find out the type of terrain and to select the appropriate technology for the collection of brushwood accordingly [20].
2) Preparatory treatment – the planning of logging begins much earlier than the physical preparation of the logging residues for subsequent use. It is necessary to take into account the collection of brushwood in the given terrain and to adapt the logging plan to it. In this way, contamination of the brushwood with earth and stones is kept to a minimum and disposal at a later date is easier. Logging is scheduled over the course of an entire year, and the schedule is drawn up according to the demands of customers. The forest management plan, which usually covers a period of 10 years, concerns the entire disposal of a forest and is set in the form of binding provisions and recommendations. These binding provisions relate to the maximum size of the logging area, its clearance, the renewal period and the minimum requirements for the amelioration and fostering of woody plants, as defined by Section No.289/1995 Sb.
3) Transport of forwarders and operators – forwarders are the first forms of heavy machinery to be transported to any site. These work independently of a wood chipper. They are transported on a low loader semi-trailer. After loading onto the low loader semi-trailer, it is necessary to properly fix the machine in place with chains, using ratchet tensioners to do so.
4) Disposal of logging residues – the disposal of logging residues is usually, but not always, the role of the seller/trader. For site identification purposes, forest roads and the edges of logging areas are demarcated with tape or signs. Piles of brushwood are required to be placed in elevated free areas, facing in a westerly direction, so that the wind can get inside more easily and make the brushwood dry faster. The piles should be no more than four metres high and wide, with vertical sides and covered, for example with a rug fixed into place with longer branches to prevent it blowing away. Piles of disposal residues should be located 10 – 15 metres apart. Such stacked piles are usually left to dry until the following summer, as a result of which their quality as fuel improves. It is also appropriate to put a sign with the name of the supplier and the total number of piles, in order to make work easier for sellers/traders who approach the site at night [21].
5) Transportation of mobile chipper and transportation unit - the mobile chipper and transportation unit are moved to the landing site. This is the place where wood is collected and weighed. The chipper is placed in close proximity to a pile of wood debris, and the transportation unit is positioned within reach of the chipper chute. The driver of the transportation unit removes the tarpaulin from the top of the trailer, making it ready for the chipping process. The operator of the mobile chipper is obliged to lower the hydraulic safety supports to ensure the stability of the machine during chipping. The supports have to sit on solid ground to be effective. In case of soil and stone contamination, it is necessary to use a shredder, which is more resistant, instead of a chipper [22].
6) Chipping and loading - chipping determines in what form biomass will be transported, which also determines the associated transport costs. Chipping or crushing (in the case of using a shredder) is performed as fieldwork, at pick-up locations or at depots, depending on the specifics of an order. Placed near the pile of disposal residue, the chipper operates at a distance given by its hydraulic arm, i.e. approximately 6–8 m (according to the load diagram). The operator

only uses the hydraulic arm to load logging residues into a draw-in table, where they are crushed by the unit to a fraction of about 6 centimeters and then blown into the attached trailer. While loading, the driver checks the quality, fraction and direction of blow. During chipping, they move their vehicle to achieve uniform load distribution. After loading, they even out the surface of the wood mass and cover the trailer with the tarpaulin. The trailer is then ready for transport [23].

7) Transport of wood chips - When the trailer is filled with wood chips, the driver is obliged to secure the load with a tarpaulin to prevent the material from flying out. The tarpaulin also serves to protect the chips from rain and snow. The tarpaulin or other devices used to anchor and protect the material need not obscure the vehicle´s registration plate, reflectors and designated lighting. The load´s weight need not exceed the maximum permissible gross weight or the maximum permissible weight per axle of the vehicle. The load has to be evenly distributed to ensure the vehicle´s maneuverability and stability.
8) Unloading - unloading is carried out using a special trailer with a tilting bed and a hydraulic system suitable for transporting dry bulky materials and goods on pallets, which makes it a universal trailer usable for all loads. Another advantage of the trailer is its rigid frame, which makes the load more secure against external damage (slitting - theft) than that of tarpaulin trailers. Upon entering the heating plant, the transportation unit´s weight is first determined by means of a weighbridge. The resulting weight is determined as the difference between the total weight of the load, including the transportation unit (the gross weight), and the weight of the unit itself after unloading (the tare weight). Chip samples are also taken to determine their dry matter content and quality. The samples may be taken either directly from the load or when unloading. Homogenization is necessary to obtain samples with informative values. Taking samples directly from the load is laborious. It is therefore easier to take samples with the use of a shovel after the material has been unloaded. A suitable sampling method is graphically shown in the following scheme (Fig. 1).

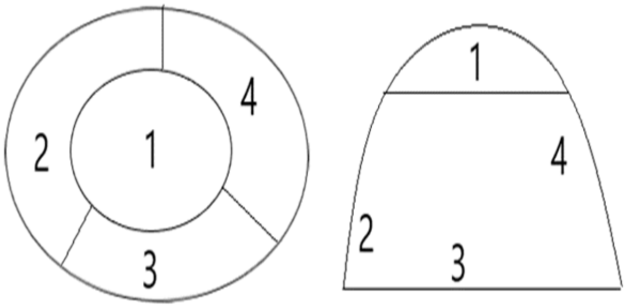

Figure 1. Sampling points (left – top view, right – side view)

The dry matter content of the samples is determined according to the following formula:

$$T = \frac{m_0}{m_w} . 100 \; [\%] \qquad (1)$$

where: T - the percentage of dry matter
m_w - the sample weight in grams before drying
m_o - the sample weight in grams after drying

The load´s dry matter content is determined according to the following formula:

$$M_0 = \frac{T}{100} . M_w \; [kg] \qquad (2)$$

where: M_o - the sought kilogram weight of the dry matter
M_w - the kilogram weight of unprocessed load (net)
T - the percentage of dry matter according to laboratory testing

3.1. Laboratory Testing

100-200 grams of properly mixed sample, weighed on laboratory scales to within the nearest hundredth of a gram, is poured into a weighing container. The weighed sample is placed in a drying room where it is dried at 103 ± 2°C until no moisture is retained [24]. The sample is then weighed again.

9) Storage - processed wood chips are stored under the following conditions:

- they do not contain impurities such as stones, gravel, plastics, metals, soil and the like;
- they are dry;
- they are free of icy lumps;
- they have the correct fractions meeting defined requirements;
- different types of biomass are differentiated during their storage [25].

4. Costs of Chip Processing

Calculating costs is important for all companies. Both direct and indirect costs have to be included in the selling price of the materials. The price of forest residues is influenced by several basic factors:

- input material price;
- haulage;
- processing;
- handling;
- transportation;
- storage.

Table 1 provides an overview of the costs for processing wood chips per cubic metre (m^3 $bv^{-1)}$ and per tonne of wood chips (t^{-1}) in CZK [15].

Table 1. Costs of processing wood chips

Operation	m3 bv^{-1} in CZK	t^{-1} in CZK
Payment to forest owner	20	70.6
Brushwood hauling	80	282.4
Chipping	100	353
Interdepot transportation	30	106
Storage	20	70.6
Loading	10	35.3
Transportation to customer 100 km	75	264.75
Margin 10 %	33.5	118.27
TOTAL	368.5	1,300.92

The transport costs are particularly influenced by:

- quantity of transported material ($t \cdot hour^{-1}$);
- form and volume of transported biomass ($t \cdot m^3$);
- vehicle capacity (m^3);
- transport distance (km);
- transport speed ($km \cdot h^{-1}$);
- vehicle fuel consumption ($l \cdot km^{-1}$).

5. Research

A specific project involving wood chip processing between the villages of Pečín and Hrádek near Trhové Sviny was selected for the proposed optimization. Timber was harvested and logged in the winter months. In order to assess and optimize the chip processing process, it was first necessary to determine the duration of each operation. During the observation period (from 20th February, 2017 to 29th November, 2017) all the necessary time data for the project analysis were measured. Due to the duration (less than 9 months) of the project and the timing of the operations, the project was divided into two sub-projects, namely *Hauling of Logging Residues* and *Chipping,* with subsequent transport of the wood mass to the heating plant in Český Krumlov. During the time interval between these two projects, the wood mass was left to dry, a process which does not play any role in this analysis.

Hauling of Logging Residues – the landing site was situated at a distance of 200 meters from the class II/156 main road from České Budějovice to Nové Hrady. There is a biogas plant in the vicinity with an installed capacity of 1000 kW. At the end of February 2019, the residues were hauled from the adjacent forest covers to the designated area near the biogas plant, which was selected because it was the most stable and accessible area for heavy machinery (Fig. 2).

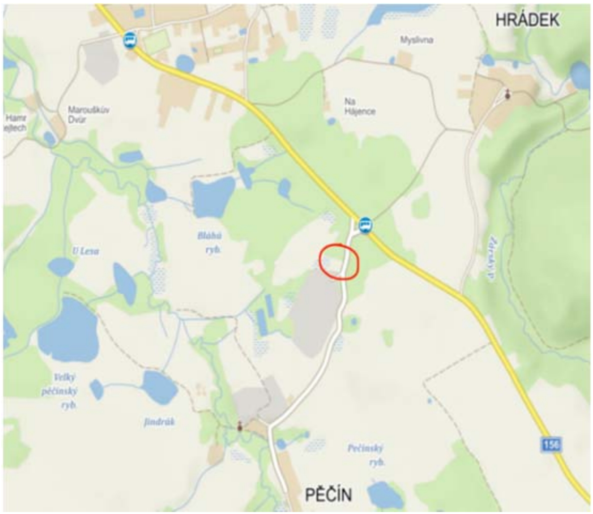

Figure 2. Landing site

Harvesting and logging took place in the winter months on an area of approximately 5 hectares. The forest consisted mainly of spruce and pine trees, with an average spruce cover stock per hectare of 400 m^3. Each cubic metre of raw wood accounts for about 35-45% of logging residues. A self-propelled multi-operation logging machine was used because it enables the cutting down of a tree in one cycle, removes its branches, cuts the trunk into predetermined lengths and stores the logs in a level pile. The advantage of using such a machine is that the removed branches and tops of trees remain on the same pile within its working radius, which makes it easier for the operator of a hauling unit. On this project, an external company was responsible for hauling the logging residues.

5.1. Application of CPM Method

With the help of MS Project, the CPM method was applied to the project to determine individual (partial) operations. The time from 6.30 a.m. to 3.00 p.m. was selected because it represented the daylight working hours during the winter months. Project planning commenced on the date the project was initiated so that it could be completed as soon as possible. The technological procedures are indicated (in bold) by the names of the operations in the programme and represent the aggregate activities (phases) of the project. In addition, a field survey and preparatory investigation were undertaken to support this, as were the moving of the hauling unit and the hauling of the logging residues.

The aggregate activities were further subdivided into individual work activities, i.e. sub-tasks and their duration, the sum of which forms a partial operation. Within this context, there are activities that take several days or just a few minutes. However, for the purposes of this analysis, hourly sequences prevail.

Another important step was to set predecessors or limitations. These define the links between operations and determine which tasks have to be completed before starting a subsequent one. The aggregate activities are presented in chronological order (Fig. 3).

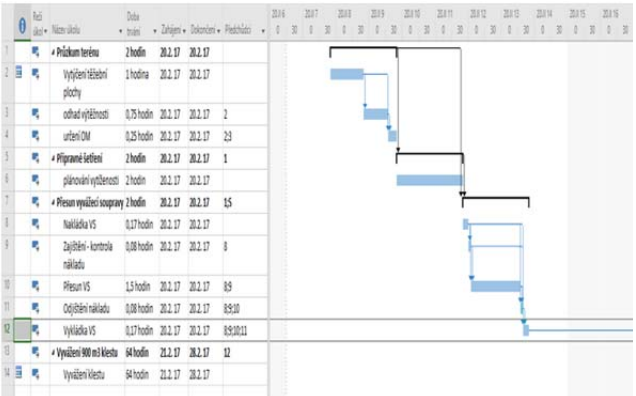

Figure 3. Project preparation

After the data set was completed, it was possible to show the course of the critical path within the whole project. For the project *Hauling of Logging Residues*, the critical path was only reflected in the process of the hauling itself, using forwarders. If this activity were extended, for example, due to machine failure or bad weather, the date of the completion of the project would have had to be deferred. Taking into account the fact that this concerns the final activity within the project without any further follow-up activities, a potential delay would not have had any significant impact. At the six-month horizon, when the wood mass is drying at the landing site, even a one-week delay is negligible.

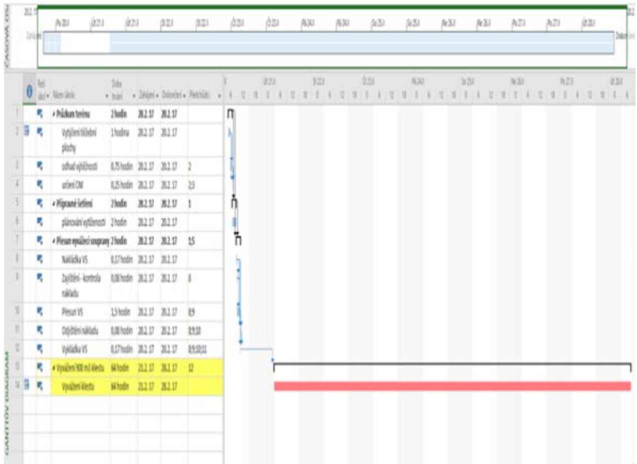

Figure 4. Gantt chart

Figure 4 shows the course of the critical path in a Gantt chart. The activities prior to hauling are carried out sufficiently far in advance, and therefore do not represent a threat for the initiation of the hauling process.

The process of the "forwarder-operator-transfer" is not incorporated into the project because the hauling of the logging residues was the responsibility of an external company. The company is paid for the cubic metres hauled, not for the hours worked.

The total hauling time could be reduced into half by using two forwarders. However, higher costs would ensue. The reduction of the hauling time is directly proportional to the increase in costs. As already mentioned, the extension or shortening of the haulage time does not have a significant impact on the time horizon for the period the residues are drying. It is therefore not necessary to increase the number of machines used.

Logging residues stored at the landing site dried for about six month, during which the excess moisture was removed and the residues were prepared for chipping.

Chipping - chipping took place at the end of the autumn, specifically on 27-29 November. The company used a Heizohack 220 kW chipper mounted to the chassis of a Mercedes Benz truck, which means it is able to move on its own axis. The unit is driven by a cardan and a reduction gear with a V-belt and is able to process logs of up to 80cm in diameter. The chipper rotor is automatically seamlessly regulated depending on the load of the draw-in device. It is also equipped with a daily and overall working hour meter. This is used if chipping is paid by the hour.

Hourly output is recommended when the logging residues are piled up within reach of the hydraulic arm, i.e. no further movement is required. If this is not the case, the machine operator has to secure the chipper after each movement using the hydraulic supports, which results in lost chipping time, sometimes several minutes. Under ideal circumstances, when no movement of the machine is required and the machine performs properly, the hourly rate for the chipper is CZK 80-90. Under less than ideal circumstances, it is recommended to agree on a price for 1 cubic meter loose volume of chipped material. The price should be approximately CZK 100.

Chipper performance is an important, but not fully indicative figure. In practice, there are several types of performance:

Flexible – in practice, this performance is achieved only for a certain period of time. It considers loss factors necessary for the operation of the machine (putting the machine into operation, adjusting the chute, inserting the wood into the machine, etc.).

Productive – this is the performance achieved by the machine for most of its operation. Chipper operation includes the time required for its maintenance and repair.

Operational – this is the performance that the machine achieves during normal operations. It takes into consideration all the factors affecting the machine´s operation, relocation, human resources, work organisation, etc.

Effective (theoretical) – this is the machine´s performance without loss factors included. It is the performance indicated by the manufacturer, which is often unachievable in practice. To achieve this performance, the machine would have to process a log with dimensions that exactly correspond to the dimensions of the inlet, so that the machine is utilised for 100%.

Chipper performance can be calculated using the following formulae:

$$W_{mpr} = \frac{m}{t_s + t_0 + t_p}\ [kg.h^{-1}] \tag{3}$$

$$W_{Vpr} = \frac{V}{t_s + t_0 + t_p}\ [m^3.h^{-1}] \tag{4}$$

where: W_{mpr} - weight hourly efficiency operational
W_{Vpr} - volumetric hourly efficiency operational
m - weight of chips
V - volume of chips
t_s - chipping time
t_o - time required for repairs
t_p - time required for preparation

The values measured are shown in Table 2.

Table 1. Values measured

Parameter	Value	Unit
Weight of chips	22 770	kg
Volume of chips	90	m^3
Time for preparation	0.1 (10)	h (min)
Time for repairs	0	h
Chipping time	1.83 (110)	h (min)

The weight of the chips is specified in the weight certificate. One cubic metre of loose volume therefore weighs 253 kg. Maintenance of the chipper was always carried out after the chipping process was finished; therefore the value is 0. If the drum knives needed to be replaced, this could be done on average within 20 – 30 minutes, dependent on the number of knives that needed to be replaced.

After incorporating the measured values into formula (3) and (4), the calculated values for chipper performance were:

Weight efficiency	*Volumetric efficiency*
12 937.5 $kg{\cdot}h^{-1}$	51.13 $m^3{\cdot}h^{-1}$

The chipped matter was transported to the heat plant in Český Krumlov, 34 km from the landing site. The average speed of a loaded truck is 35 $km{\cdot}h^{-1}$, while in the case of an unloaded truck it is 45 $km{\cdot}h^{-1}$. The individual driving times (in minutes) can be calculated using the following simple formula:

$$t = \frac{s}{v}.60\ [h] \tag{5}$$

where: t - driving time of a loaded truck from the place of loading to the heat plant in Český Krumlov
s - distance between the place of loading and the heat plant in Český Krumlov [km]
v - average speed of the truck [$km{\cdot}h^{-1}$]]

On the basis of the above data and formula (5), it is possible to calculate the overall driving time for both a loaded and unloaded truck heading back to the place of loading. The overall driving time of a loaded truck is 58 minutes (after rounding), and for an unloaded truck returning to the place of loading, 45 minutes (after rounding).

For the chipping project, two trucks with a tilting bed and a capacity of 90 cubic metres loose volume (m^3 bv) were used. Other trucks were used for other orders. The time for unloading - initial weighing, material unloading and subsequent final weighing - took 23 minutes on average.

The programme settings for the *Chipping* project were the same as for the *Hauling of Logging Residues* project, with the exception that the working hours were from 7.00 a.m. to 5.00 p.m.

Numbers were added to individual tasks so as to assign them correctly. Chipping and loading are concurrent activities; therefore there is a limitation with regards to determining whether the loading process will not finish until the chipping is (Finish-to-Finish). After loading, the material is transported to the heat plant in Český Krumlov, where it is unloaded. To show in which direction a truck is headed, the letter P indicates Pěčín, and the letter CK indicates Český Krumlov. After unloading Load 1, Truck 1 goes back to the landing site to receive Load 3. Prior to the completion of Load 1, Truck 2 is ready at the landing site to receive Load 2. Load 3 has both the predecessor (the truck has to first arrive at the landing site) and limitations set (loading completion time = chipping completion time). After that, the tasks and their settings are repeated.

At the end of the working hours on the first two days, Truck 1 has reserve time, time which could be utilised for loading one more time, but without sufficient time for driving back and forth. The trucks therefore transport four loads a day (each truck transporting two loads). On the last day, there was only one truck for transporting the material, which created an undesirable time window. However, under the given circumstances, this could not be resolved in any other way.

Figure 5 shows the time axis for the whole chipping project, which lasted almost three days. According to MS Project, the chipping project took 1,694 minutes from the start of the first chipping to the transfer of the empty truck to the seat of the company. The whole chipping project therefore ended at Pěčín near Trhové Sviný.

Figure 1. Time axis of chipping project

Grey - project duration, Green - chipper related tasks, Blue - Truck 1 related tasks, Orange - Truck 2 related tasks

Process optimization

As stated, the chipping project took 1,694 minutes. When a chipper with a power of 45 prm·h^{-1} is used, it is theoretically possible to chip 5 semi-trailers with a capacity of 90 m^{3}st per working day. However, when taking into account working hours, it was only possible to chip 4 semi-trailers, which meant that the driver transporting the last load was able to return before the end of their working hours. Another limitation was also the number of trucks, i.e. two for the first two days and one on the last day. These factors influenced the duration of the project.

In order to minimise and streamline the whole chipping project, it is necessary to determine which processes can be shortened. Within this context, neither the transport distance and time, nor the time required for unloading can be shortened. It is therefore only possible to shorten the time required for chipping or loading, which are concurrent processes. Using a more efficient chipper with a power of prm·h^{-1} (operational performance is approx. 120 prm·h^{-1}) reduces the chipping and loading time by half. This would create considerable reserve time between the individual chipping processes. It is therefore necessary to streamline the whole project by using the full capacity of the tilt bed semi-trailers. Currently, the company has three such semi-trailers. For the calculation and graphical representation, MS project was used.

For greater clarity with regards to the use of the three trucks, a Table 3 with process start and end times was created. The line colours correspond to the division in the time axis.

Table 2. Process start and end times

Chipping (Loading)		Available again (transport-unloading-transport)	Truck (T)	Load number
Start	End			
6:00	6:45	8:51	T 1	1
6:45	7:30	9:36	T 2	2
7:30	8:15	10:21	T 3	3
8:51	9:36	11:42	T 1	4
9:36	10:21	12:27	T 2	5
10:21	11:06	13:12	T 3	6
11:42	12:27	14:33	T 1	7
12:27	13:12	15:16	T 2	8
6:00	6:45	8:51	T 1	9
8:51	9:36	11:42	T 1	10

The Table 3 shows that a reserve time of 36 minutes is created after every third loading. The chipper is able to process 720 m^{3}st of wood per working day, which corresponds to the capacity of eight fully loaded semi-trailers. For the last working day, there are only two loading processes left; therefore only one truck is used, although a reserve time of 126 minutes is created between the individual loading processes. The remaining trucks will show a higher level of daily transport than if they were used to complete the transportation process of the remaining material.

Figure 6 shows the time axis with the proposed changes are included. The time required to chip 900 m^{3}st of logging residues was reduced from nearly three days to a day and a half, more specifically from 1,694 min to 944 min, thereby generating savings of 750 minutes.

Figure 2. Time axis of optimised project

The total duration of the project is indicated in grey. Green represents chipper related tasks, light blue represents Truck 1 related tasks, orange represents Truck 2 related tasks, and dark blue represents Truck 3 related tasks.

The process of determining tasks and their predecessors or limitations is the same as in the original project, with exception to the loading and chipping time, which was reduced by using a more efficient chipper and deploying three trucks with tilt bed semi-trailers. All other times remain unchanged. The chipping project is completed at the moment when Truck 1 arrives at the seat of the company after unloading the last load. The network diagram in Figure 7 shows the project´s critical paths after optimization. The course is similar to the original chipping project, but the chipping and loading time is reduced, which resulted in the addition of the tasks related to the deployment of the third truck. The critical tasks remained unchanged, but the overall period of time required for processing the given volume of logging residues was reduced by one working day.

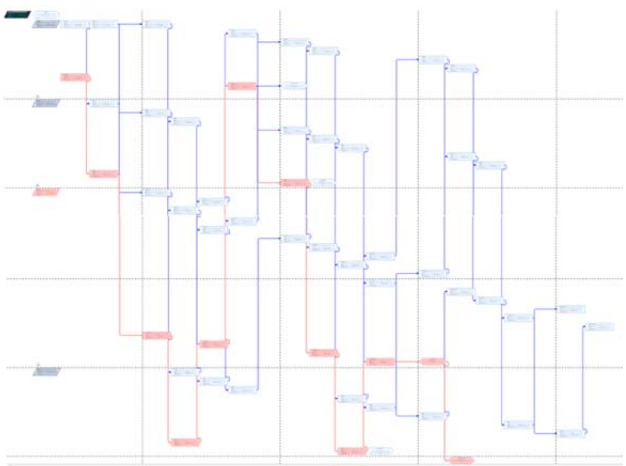

Figure 7. Course of critical path after optimization

5.2. Assessment

The company will require an investment loan of CZK 12,700,000 for the purchase of the new chipper. When applying for a loan, the applicant (the company) has to prove that its income is sufficient to repay the loan and that there is no immediate risk of default. For this purpose, a so-called business plan has to be submitted that is simple, realistic and convincing.

On a loan of CZK 12,700,000, the monthly payment for five years is CZK 228,315.26. Within this context, it is important to conduct an economic evaluation of the costs of processing residues into wood chips on the basis of a subcontracting model (for m3st) compared to that using a chipper purchased on credit.

For the comparison, the following parameters were set:

Price for supplying wood for processing into wood chips: CZK 100/m^3st

Power of contracted machine: about 45m^3st/h

Annual volume of material processed on subcontracting basis (wood chips): 81,000 m^3st

Annual cost: CZK 8,100,000 (Table 4)

Table 3. Expenditures (in CZK) on machine by years

Year	Repairs fund	Depreciation	Interest on loans	Wage costs	Operational costs	Total
1	524,793	2,099,174	350,651	671,378	870,800	4,516,796
2	524,793	3,358,678	277,492	671,378	870,800	5,703,141
3	524,793	2,519,008	202,092	671,378	870,800	4,788,072
4	524,793	1,679,338	124,384	671,378	870,800	3,870,694
5	524,793	839,669	44,297	671,378	870,800	2,950,937
Total	2,623,966	10,495,867	998,915	356,890	4,354,000	21,829,640

The following parameters were used in order to calculate the costs:

- Chipper purchasing price (PP): CZK 10,495,867
- Performance: 120 m^3st/h
- Annual wages and other personnel costs: CZK 671,378
- Annual (other) operational costs: CZK 870,800
- Annual repairs fund: CZK 635,000 (5 % of PP)
- Annual return: CZK 8,100,000

For the calculation of the return on investment and payback period, a table of costs and revenues over a five year horizon was created.

The investment would constitute a change in the cost base and volume of production, which will be reflected in the profits. The calculation reveals that investment in a chipper would deliver an average net profit of 30.24%.

6. Conclusion

The analysis in this paper concerns a project focused on the production of wood chips. The project ran between 20 February, 2017 and 29 November, 2017 in the village of Pěčín near Trhové Sviný. The project was divided into two sub-projects: *Hauling of Logging Residues* (20-28 February, 2017) and *Chipping* (27-29 November, 2017). In the period between the two projects, the logging residues were left to dry. The information and data obtained were presented using the MS Project programme. The analysis of the current situation showed the course of the critical paths and the overall project duration, on the basis of which proposals were put forward to shorten it.

The main proposal was to purchase an efficient chipper, the use of which would significantly reduce the chipping and/or loading time. An investment loan of CZK 12,700,000 would be required. The investment was evaluated by means of financial indicators using the ROI method and payback period. These indicators proved that investing in the purchase of a new chipper would be the right step in order to strengthen the company´s position on the market for wood chips. Compared to the subcontracting model for chipping, the return on investment would be achieved within 3 years and 1 month. According to the ROI method, the investment would generate an average net profit of 30.24 % for the company. A condition for the effective use of the new chipper was the deployment of a third truck, which would reduce the project duration time by one working day.

The processing of 900 m^3st of logging residues initially took 1,694 minutes, and after optimisation, 944 minutes, thereby providing a reserve time of 750 minutes. As a consequence, the company is currently awaiting a quote for the purchase of a new chipper.

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